Measuring Greenhouse Gas Benefits of Efficiency Programs

by

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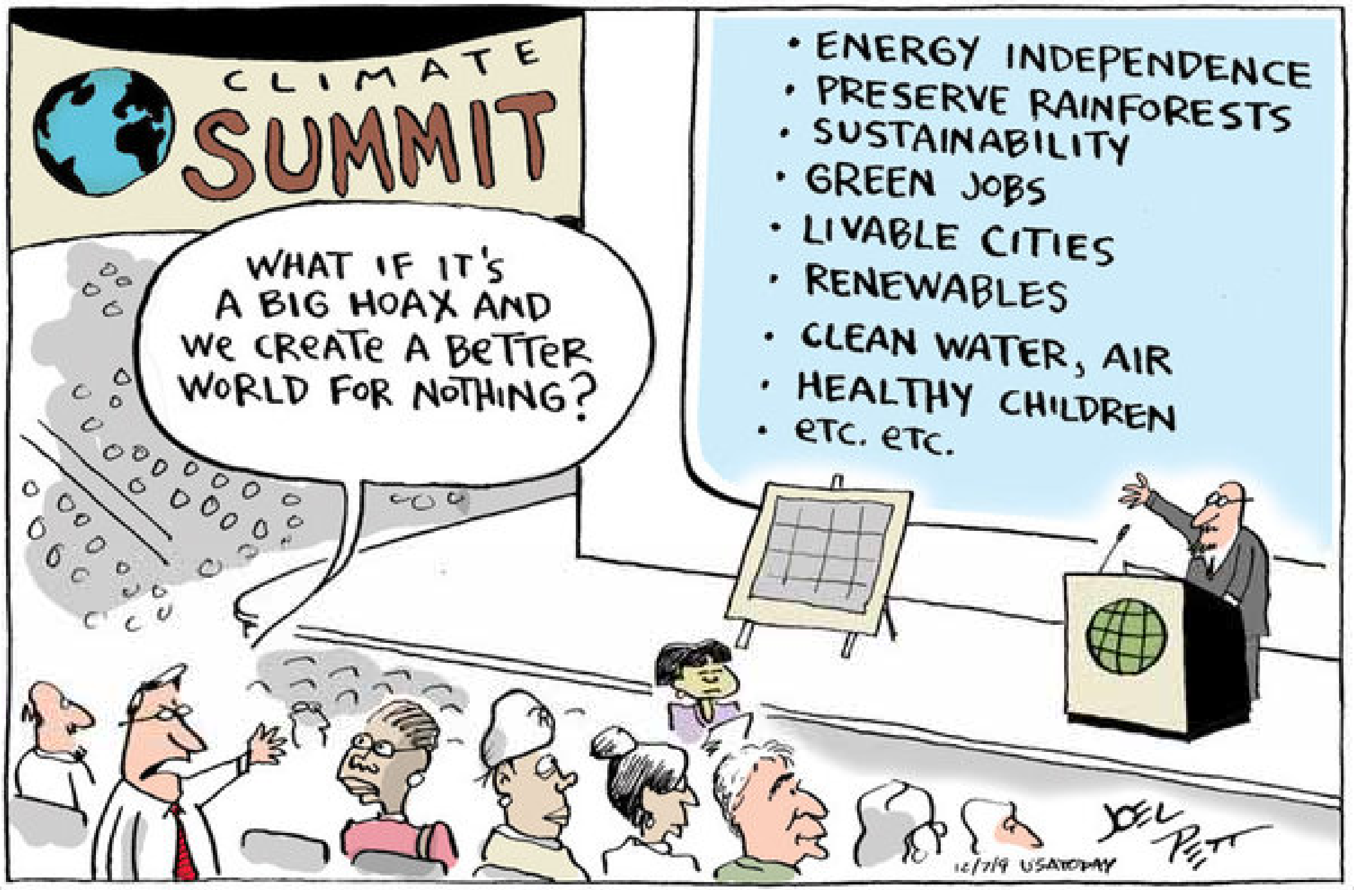
- As efficiency is seen as a key strategy to mitigate green house gas emissions measuring savings is becoming an increasing important topic.



- This paper is focused on methods to measure the avoided tons of CO_2 emissions from conservation and peak shifting technologies and utility programs.

What we are NOT describing

- We are not describing the cost of greenhouse gas emissions.

What we are NOT describing

- Without the $/ton cost of CO_2 emissions, we cannot determine:
  - Cost-effectiveness,
  - Optimal CO_2 abatement,
  - Or other policy questions.

What we ARE describing

- In this paper we describe the methods used to estimate the tons of CO_2 avoided.
- We call tons of CO_2 avoided Claimed Emissions where:

Claimed Emissions = Emissions Rate * kWh Savings

What is the Emissions Rate

- The emission rate can have both a Building Margin (BM) and Operating Margin (OM) component.

  - Build Margin (BM) = avoided new capacity
  - Operating Margin (OM) = Generation displaced from existing power plants

OM Calculation Methods

In the order of increasing precision and stringency the OM calculation methods are:

1. **Average load-following.** Calculates the average annual emissions of load-following power plants.
2. **Average marginal.** Weighted average by resource type on the margin at specific time periods.
3. **Marginal historic.** Historical data to calculate marginal emission rates by hour.
4. **Marginal modeled.** Dispatch modeling to calculate marginal emission rates by hour.

Key Issues

- When considering which methods to use there are several key issues to think about.
  - Rigor Required
  - Data available
  - Baseline techniques to use
  - Margins
  - Programs being applied to

Example Applications

- To illustrate the differences between a peak hour weather sensitive measure and non-weather responsive off-peak measure, we look at a couple conservation programs including:
  – An LED Street lighting program and
  – A high efficient HVAC program.
- Additionally we look at two recent demand response demonstration studies from the northern Minnesota and Midwest regions.

Example Applications

- All of the calculation methods require information about the marginal supply stack. Specifically, we required information about:
  - Which generator is on the margin
  - The unit emission rate
  - The fuel type
  - The amount of time each generator is expected to operate
  - The more rigorous tests need information that aligns savings with generation

Method 1 – Average Load Following Resource

- Method 1 calculates the average annual emissions of power plants that are not baseload or must-run.
- Ideally, actual emissions information is available from emissions monitoring systems (the CEMS data for example).
- When actual emission data is not available for all plants information about the amount of time each unit generates is needed to calculate its contribution to the average emissions rate.

Method 1 – Average Load Following Resource

- The following table calculates the weighted average emission rate using this method.
- As shown, a single number is calculated and used in the savings analysis.

Month	Unit	Generation MWHr	Hours Run/Mth	Capacity Factor Hrs Run/Mth/ Total Hrs/Mth	Outage Rate	LBS CO2/kWh	Total LBS CO2	Weighted Average Rate - LBS CO2/KwH
Jul	Linn -CT	0	0	0	8	1.129	0	**1.548**
Jul	Mill-Beech-CT	0	0	0	5	1.142	0	
Jul	CT4-New-B	31516	56	8	7	0.749	23.62	
Jul	CT3-New-B	27454	92	12	7	0.749	20.57	
Jul	CT1-New-B	23354	41	6	7	0.749	17.50	
Jul	CT2-New-B	18873	33	4	7	0.749	14.14	
Jul	Rockford	248548	301	40	2	1.119	278.13	
Jul	Grant-CT-Fut	14930	373	50	2	0.749	11.19	
Jul	Clifton-2	14960	394	53	7	2.055	30.75	
Jul	Clifton-1	15057	396	53	7	2.124	31.98	

Method 1 – Average Load Following Resource

- Using this method, both the weather responsive HVAC measure and the street lighting program will have an identical per kWh CO_2 saving impact.
- That is because the method does not take into account the hours that the measure saves. Both Off-peak load shifting and peak hour programs will give identical results.

Method 2 – Average Marginal Duration Curve

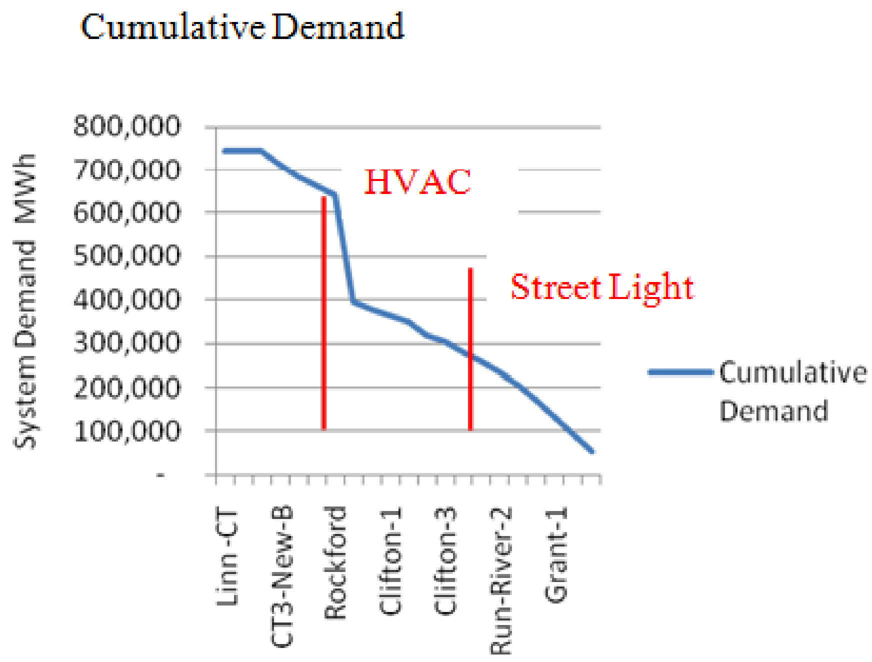
- In addition to information about the supply stack, Method 2 uses information about cumulative demand to calculate the expected CO_2 benefit.
- In the example below, the cumulative demand is aligned with the marginal cumulative supply curve to calculate the load weighted average emissions rate over the period impacted by the program.

Method 2 – Average Marginal Duration Curve

- In this example cumulative load duration curves are used to arrive at an appropriate rate.

Cumulative Emissions Rate

Unit	Cumulative Demand	Cumulative Percent	Average Cumulative Rate
Linn -CT	743,877	100%	1.548
Mill-Beech-CT	743,877	100%	1.548
CT4-New-B	743,877	100%	1.548
CT3-New-B	712,361	96%	1.584
CT1-New-B	684,907	92%	1.617
CT2-New-B	661,553	89%	1.648
Rockford	642,680	86%	1.674
Grant-CT-Fut	394,132	53%	2.024
Clifton-2	379,202	51%	2.074
Clifton-1	364,242	49%	2.075
Buick-3	349,185	47%	2.073
Buick-4	319,531	43%	2.075
Clifton-3	304,490	41%	2.073
Clifton-4	281,020	38%	2.071
Run-River-1	257,628	35%	2.075
Run-River-2	232,362	31%	2.079
Riverdowns-5	205,957	28%	2.075



Method 2 – Average Marginal Duration Curve

- In the case of a high efficient HVAC programs vs. street lighting programs:
  - Weather related extreme conditions can be distinguished from lighting demand if appropriate load duration curves are available for each system condition.

Method 3 – Marginal Historic Emissions

- The advantage of this method
  - Does not require forecasting demand or supply.
- The disadvantage of this method
  - Structural shifts such as the addition of new supply, retirements, or forced outages are not easily captured.
- The method is able to adequately measure the difference in emission benefits between our two programs, but only from the perspective of the historic comparison year.

Method 3 – Marginal Historic Emissions

- For our example programs, the historic hourly data will capture changes in peak and off-peak emission rates.
- However, the use of a single average historic weather year will result in a random stacking of supply resources.
- Extreme weather conditions may or may not be reflected in the historic data and the full range of weather conditions over several years will not be accurately understood.

Method 4 – Marginal Modeling

- The modeling approach is by far the most difficult. However the results from this method better address several difficulties not possible using the previous methods.
- Specifically, the method is able to both consider the impact of structural shifts and to accurately capture differences in program benefits due to regional, hour of day, and seasonal operational characteristics.

Method 4 – Marginal Modeling

- The modeling approach typically uses some kind of engineering model to translate the changes in future supply and demand into actual CO2 savings.
- The method requires information about:
  - Expected supply additions
  - The marginal cost of supply including dispatch order
  - Pollution abatement technology that may be deployed during the life of the DSM measure
  - Changes in end-use and system load

Method 4 – Marginal Modeling

- Although the method is often used with sophisticated chronological dispatch production cost models, less complicated models can also be used.
- For example, the DSMore approach described below is a modeling approach, but also relies on information derived from previous methods. A case study using DSMore is discussed below.

Midwest Case Study – The Utility of the Future

- In this study demand response and conservation programs related to Utility of the Future demonstration technologies are analyzed for commercial and residential customer classes.
- The per-participant reduction in CO_2 generation and the associated value of CO_2 reduction is reported using the expected forward resource mix displacing marginal generation as demand resources are deployed.

Midwest Case Study – The Utility of the Future

- The results are consistent with a typical dispatch order. Initially gas generation is displaced.
- The results are reported as total lbs reduced. At 500 hours deployed and 10% reduction the program can provide up to 3,565 marginal lbs of CO2 reduction.

Hours Deployed

	20	40	60	80	100	150	200	250	300	350	400	450	500
1%	15	30	45	60	75	116	157	196	234	265	297	327	356
2%	30	60	90	120	150	232	314	391	468	531	593	653	713
3%	45	90	135	180	226	349	472	587	702	796	890	980	1,069
4%	60	120	180	241	301	465	629	782	936	1,061	1,187	1,306	1,426
5%	75	150	226	301	376	581	786	978	1,170	1,326	1,483	1,633	1,782
6%	90	180	271	361	451	697	943	1,173	1,403	1,592	1,780	1,959	2,139
7%	105	211	316	421	526	813	1,100	1,369	1,637	1,857	2,076	2,286	2,495
8%	120	241	361	481	602	930	1,257	1,564	1,871	2,122	2,373	2,612	2,852
9%	135	271	406	541	677	1,046	1,415	1,760	2,105	2,387	2,670	2,939	3,208
10%	150	301	451	602	752	1,162	1,572	1,955	2,339	2,653	2,966	3,265	3,565

Minnesota Case Study –
Arbitraging with Dynamic Dispatching

Between Supply, Grid and End Uses

- Many end uses (e.g., space and water heating) create added value to utilities when they are dynamically dispatched alongside local supply, grid and renewables.
- In this example, a heating end use is dynamically dispatched within a market with 20% wind resources in the supply mix.

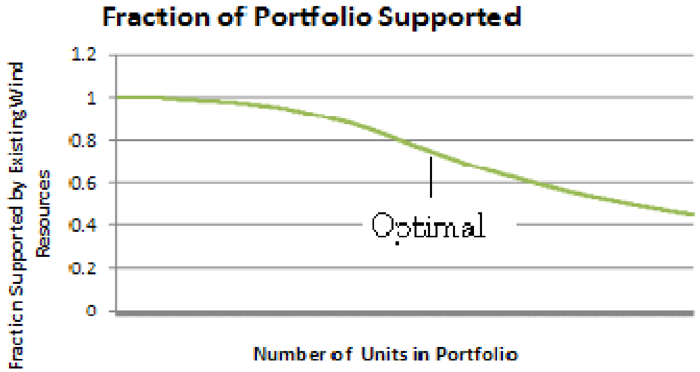
Minnesota Case Study –
Arbitraging with Dynamic Dispatching

Between Supply, Grid and End Uses

Spot Price (Grid) Arbitrage Value	$ 6,200
Wind to Grid Arbitrage Value	$ 8,540
Wind Availability (Firming) Value	$ 1,260
Hot Water Heat Shifting Value	$ 130
Heat Pump with Secondary Arb Value	$ 1,800

$2,400 = Simple Peak/ Off Peak Dispatch
$3,800 = Dynamic Dispatching
$6,200 = Arbitrage Value (from End Use Only)

Value after we dispatch, given Wind
Value added from a good Wind Forecast



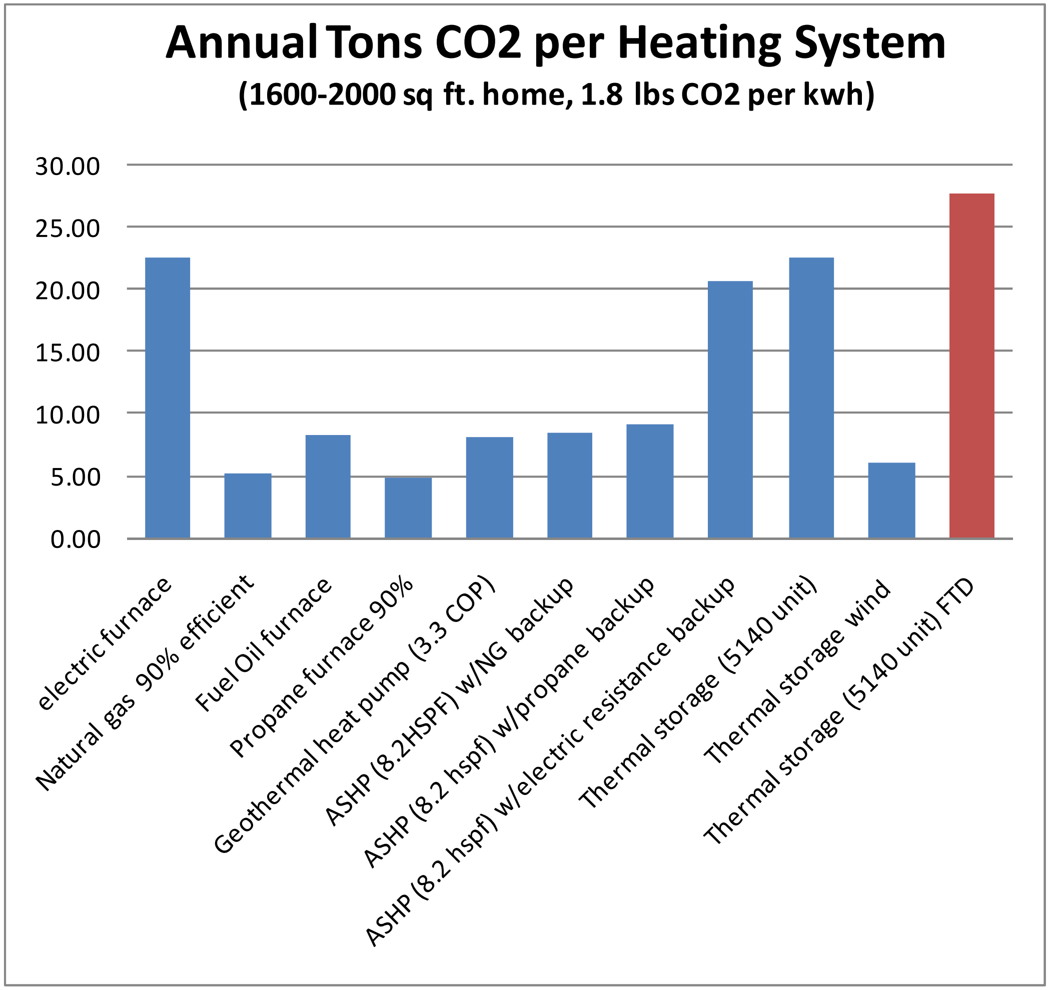
For a given supply mix, known renewables and forecastable volatility/ intermittency, we can determine the optimal market shares of dispatchable end uses to pursue.

Note how end use value increases as we vary operational dispatch. At a $10,000 cost, ~80% of heating equipment is recouped (WindStore/IDROP, IA).

Minnesota Case Study

Comparing the carbon footprint across technology

– Given and average household heating demand of 25,000kWh, the following chart compares carbon emissions by technology



Design & Operations Implications

- While this paper focuses on the methods for measurement, it is critical to understand how this might be used in the future for program planning, design and operations.
- In the past program design had been driven primarily by the dollar value savings from peak reduction on the margin. It focused on how much a program could save to lower peak requirements and that monetary value.

Design & Operations Implications

- With a stronger greenhouse gas objective and more monetary connection with carbon reduction, energy efficiency and demand response programs could change emphasis and overall design.
- These designs might change in the following manner:
  - Technologies.
  - Target Markets.
  - Demand Response.

For more information

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